Evaluation of Renal Function in Children Undergoing Extracorporeal Shock Wave Lithotripsy

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Purpose: The effect of extracorporeal shock wave lithotripsy on the growing kidneys of young children has always been a concern. We determined whether shock wave lithotripsy causes renal parenchymal scarring or affects glomerular filtration rate in children.

Materials and Methods: This prospective study included 100 children with renal stones who presented to the shock wave lithotripsy unit at our institution between March 2005 and March 2008. A total of 28 children had multiple stones in the same kidney. All children with bilateral renal stones had 1 kidney cleared of stones by percutaneous nephrolithotomy before undergoing shock wave lithotripsy. A total of 138 stones were subjected to shock wave lithotripsy. All children underwent radionuclide scan of the renal parenchyma using dimercapto-succinic acid, and glomerular filtration rate was estimated using diethylenetriamine pentaacetic acid before extracorporeal shock wave lithotripsy and 6 months afterward. Children with renal scarring due to previous surgery or vesicoureteral reflux were excluded from the study. The number of shock wave lithotripsy sessions to achieve stone-free status and the dose of shock waves used were recorded for each patient.

Results: No patient demonstrated renal parenchymal scarring on dimercapto-succinic acid scan or any statistically significant change in glomerular filtration rate on diethylenetriamine pentaacetic acid scan up to 6 months after shock wave lithotripsy.

Conclusions: Shock wave lithotripsy is a safe modality for treating renal calculous disease in children up to 16 years old, with no impact on long-term kidney function.

Key Words: child, cicatrix, kidney calculi, lithotripsy, radionuclide imaging

Abbreviations and Acronyms

^{99m}Tc = ^{99m}technetium

DMSA = dimercapto-succinic acid

DTPA = diethylenetriamine pentaacetic acid

GFR = glomerular filtration rate

PCNL = percutaneous nephrolithotomy

SWL = shock wave lithotripsy

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Shock wave lithotripsy has revolutionized the management of urinary calculi, contributing significantly to the treatment of renal and ureteral stones.[1,2] Shock wave lithotripsy has been used increasingly as a therapeutic modality for most pediatric urolithiasis.[3,4] Open surgery is reserved for cases with anatomical abnormalities, large stone burden or failed minimally invasive procedures, while shock wave lithotripsy in general is becoming the method of choice for managing the majority of upper urinary tract calculi in children.[5,6] Good results may be attributed to better shock wave transmission through the smaller body volume, in contrast to the larger course the wave has to travel in the adult body.

Multiple studies document the safety and efficacy of SWL in children with an overall stone-free rate of 79.9% at 3 months of followup.[7–9]

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However, the long-term safety of shock waves on pediatric renal units is not proved. The effect of SWL on the growing kidneys of young children has always been a concern. We determined whether SWL causes renal parenchymal scarring or affects glomerular filtration rate in this population.

PATIENTS AND METHODS

This prospective study included 100 children 3 to 14 years old with renal stones who presented to the shock wave lithotripsy unit at our institution between March 2005 and March 2008. A total of 28 patients had multiple stones in the same renal unit. Children with renal scarring due to previous surgery or vesicoureteral reflux were excluded from the study, as were those with bilateral renal stones, radiolucent stones or any compromise in renal function of the affected side that might be due to long-standing obstruction.

SWL was used to treat 138 stones with a total of 153 sessions. All children underwent lithotripsy using the same device with a gradual incremental energy increase from 14 to 20 kV.

Before treatment children were evaluated by plain radiography, abdominal ultrasound (to estimate number and size of stones and degree of hydronephrosis) and excretory urography. All children underwent static radionuclide scan for detection of renal parenchymal scarring using DMSA, and GFR was estimated using DTPA before SWL and 6 months after the last session.

The procedure was done with patients under general anesthesia using 1.5 mg/kg ketamine and 0.05 mg/kg midazolam. Intravenous fluid was administered throughout the procedure. All patients were treated in the supine position. Older children fit into the gantry with no need for modification. Small children required placement of tape under the body for suspension. The water cushion was adjusted according to body configuration. Besides the tape the water cushion prevented sliding of small children from the gantry. The device used was the Dornier Lithotriptor S with the 220 electromagnetic shock wave emitter. Fluoroscopy was used for stone localization.

Patients were kept for 3 hours under observation until becoming fully conscious and urine was relatively clear of hematuria. On discharge from the hospital mothers were instructed to maintain an adequate fluid intake for their children. An analgesic was prescribed on discharge home. Parents were also instructed to check for expected hematuria and passage of stone fragments, and to report if the patient had fever or colic.

We recorded the dose of the shock waves used, together with the total number of sessions needed to render the patient stone-free. Patients were reevaluated by plain radiography and abdominal ultrasound 2 and 4 weeks after the SWL session. Those who had sizable fragments were scheduled for another session 4 weeks later. The maximum number of sessions allowed for our patients was 3, and those who did not become stone-free were scheduled for PCNL.

SWL was considered successful if patients were rendered stone-free as evidenced by the absence of any visible fragments on plain radiography done after SWL or if the stones were fragmented to clinically insignificant size, defined as asymptomatic noninfectious and nonobstructive fragments smaller than 4 mm by ultrasound. Unsuccessful SWL was defined as lack of evidence of disintegration or fragmentation on plain radiography and ultrasound after 3 SWL sessions. All children underwent radionuclide scan using DMSA and estimation of the GFR using DTPA 6 months after the last SWL session. We calculated GFR based on a modified Schlegel program developed by Gates, which involves computer analysis of scintigraphic images of the kidneys after a single intravenous injection of ^{99m}Tc DTPA.[10]

Statistical analysis was performed using SPSS®, version 14 for Windows. Results were expressed as mean ± SD or rate (%). Comparison of mean values among the 3 groups (multiple group comparison) was performed using one-way ANOVA, while comparison between groups was performed using Student's t test. Comparison between categorical data (number/percent) was performed using chi-square test. Spearman's rank correlation coefficient was used to determine significant correlations among different parameters. A p value of less than 0.05 was considered statistically significant.

RESULTS

A total of 58 boys (58%) and 42 girls (42%) were included in this study. Mean patient age was 7.95 years (range 3 to 14). All patients had radiopaque renal stones.

A total of 138 stones were treated by SWL. Of the patients 10 (10%) had 3 renal stones, 18 (18%) had 2 renal stones and the remainder (72%) had a single renal stone. Mean stone size was 12.1 mm (range 8 to 27). Mean number of shock waves administered was 2,000 (range 800 to 2,600).

The average number of sessions was 1.53. Of the patients 60% required 1 session, 27% required 2 sessions and 13% required 3 sessions of SWL. Stone burden showed a proportional significant relation to the number of sessions required to achieve the maximum result.

Table 1 outlines the relation between stone burden and number of SWL sessions. The overall stone-free rate was 88%. Complications encountered in 11 patients included renal colic associated with passage of stone fragments (8) and impacted lower ureteral stones with subsequent uncomplicated hydronephrosis requiring ureteroscopy after failure of med-

Table 1. *Relationship between stone burden and number of SWL sessions*

Stone Size (mm)	No. Pts	% Stone-Free	Av No. Sessions
Less than 10	11	100	1.09
10–20	58	98.2	1.2
Greater than 20	31	64.5	2.3

ical therapy (3). No perirenal hematoma or ecchymosis was detected by ultrasound on followup in any patient.

All children underwent radionuclide scan of the renal parenchyma using DMSA and GFR was estimated using DTPA before SWL. As mentioned previously, no patient had renal scarring before SWL. Radionuclide renal scanning was performed 6 months after the last session of SWL for all patients except those with residual stones after the third session (12%). Those cases were considered SWL failures and PCNL was planned. In those patients the radionuclide scan was done only 1 month after the third session so as not to delay the planned PCNL.

None of the patients in this study exhibited any degree of renal scarring on DMSA scan or any decrease in split kidney function as evidenced by GFR measurement in ml per minute using DTPA after SWL. Mean ± SD total GFR was 113.13 ± 4.51 ml per minute (range 100 to 123) before SWL and 113.01 ± 4.27 ml per minute (104 to 121) after the last session. Mean ± SD split function of the affected kidney unit was 50.05% ± 1.48% (range 46.9% to 53.3%) before SWL and 50.05% ± 1.47% (47% to 53.1%) after SWL. None of these changes was statistically significant. Table 2 outlines the relation between split function and total GFR before and after SWL.

Table 2. *Relationship between split function and total GFR before and after SWL*

	Mean ± SD (range)	p Value*
% Split function:		0.245
Before SWL	50.069 ± 1.48 (46.9–53.3)	
After SWL	50.05 ± 1.47 (47–53.1)	
Ml/min total GFR:		0.460
Before SWL	113.13 ± 4.51 (100–123)	
After SWL	113.01 ± 4.27 (104–121)	

* Difference is considered statistically significant at $p < 0.05$ and highly significant at $p < 0.01$.

DISCUSSION

We prospectively studied 100 children to assess the efficacy and safety of SWL in treating renal calculi. Following treatment of 138 stones 88% of patients became stone-free. Mean number of procedures required was 1.53. Although our stone-free rate was higher than that published by Brinkmann[11] (83%) and Rizvi[12] (84.2%) et al, others such as Rodrigues Netto et al have reported higher stone-free rates up to 97.6%.[13]

In this study we needed an average of 1.53 sessions per patient. Of the patients 60% required 1 session, 27% required 2 sessions and 13% required 3 sessions of SWL. Our rate is much less than those reported by Onal[14] and Elsobky[15] et al, who observed 39% and 64% repeat treatment rates, respectively.

Mean number of shock waves per session was 2,000 (range 800 to 2,600). Mean power used was 17 kV (range 14 to 20) per session.

To evaluate stone clearance by size, stones were classified according to largest diameter into stones less than 10, 10 to 20 or greater than 20 mm. The impact of overall stone burden on stone clearance, presence of residual fragments, repeat treatment rates and rate of complications was evaluated. Our stone-free rates were 100%, 98.2% and 64.5% for the smallest to largest stones. For stones less than 10 mm our stone-free rate of 100% is superior to that reported by Elsobky et al (92%),[15] and compares favorably with the results of Ather and Noor (97%).[16] For stones 10 to 20 mm our stone-free rate of 98.2% was superior to the rates reported by Elsobky et al (76%),[15] and Ather and Noor (88%).[16] For stones 20 to 27 mm our stone-free rate of 64.5% was less than the rates observed by Muslumanoglu[9] (86.7%) and Al-Busaidy[17] (79%) et al. Thus, we conclude that the larger the stone burden, the greater the number of SWL sessions required and the lower the stone-free outcome.

Renal colic, which developed in 8 cases (8%) after SWL due to passage of stone fragments, was managed conservatively. Three patients (3%) required ureteroscopy for obstructing steinstrasse. Transient hematuria occurred in all patients. Gross hematuria lasting 24 to 48 hours resolved with increased oral fluids, and no patient required hospitalization or blood transfusion. Similar observations were reported by Kotb[18] and Lottmann et al.[19] None of our patients exhibited perirenal or subcapsular hematoma. Muslumanoglu et al reported no incidence of hematoma,[9] while Slavkovic et al reported an incidence of 16.7%.[20]

GFR, the volume of plasma ultrafiltrate produced per minute by renal glomeruli, is an important index of renal function. The 24-hour creatinine clearance, one of the most commonly used methods for determining GFR, overestimates GFR in patients with impaired renal function due to a small element of tubular excretion that becomes more significant as glomerular function decreases.[21]

The gold standard methods for determining GFR include inulin and iothalamate clearance, which are expensive, time-consuming and highly dependent on collection accuracy.[22] A variety of methods exist for estimating GFR following injection of ^{99m}Tc DTPA, an agent commonly used for renal scintigraphy. These methods are well described by Dubovsky and Russell.[23] DTPA is excreted solely by the glomerulus, theoretically making it a good agent for determining GFR.[24] Some methods depend on measuring clearance of the agent from blood or urine samples,[25] while others call for measuring reduction of ^{99m}Tc DTPA by monitoring diminution of radioactivity from blood by a detector placed over the precordium.[10] An additional method, a modification of the Schlegel program dexveloped by Gates, involves computer analysis of scintigraphic images of the kidneys after a single intravenous injection of ^{99m}Tc DTPA.[26] This is the method used in our study.

None of the patients in this study had renal scarring after SWL, as seen on the DMSA renal scan, regardless of the stone burden and number of SWL sessions needed. Also, there was no statistically significant difference in total GFR or split function of the affected kidney before and 6 months after SWL regardless of the number of sessions required.

Our results were comparable to those of Traxer et al.[27] As for functional outcome after SWL, our assessment of GFR by DTPA at 6 months after the last SWL session was also comparable to the study conducted by Vlajkovic et al.[28]

CONCLUSIONS

SWL is considered a safe treatment modality for pediatric renal stones. Its use is not associated with a significant impact on kidney function or subsequent renal scarring, regardless of stone size (up to 2.7 cm) or number of SWL sessions (up to 3).

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EDITORIAL COMMENTS

These authors address the clinically important question of whether SWL causes renal parenchymal scarring or affects glomerular filtration rate. Based on their findings, it appears that SWL is safe in childhood regardless of stone burden and number of sessions. These findings are consistent with the literature (reference 27 in article).[1] Strengths of the study include its prospective design and the number of stones treated. Although encouraging, enthusiasm should be tempered with caution. Unfortunately all of these patients were treated on the same machine and a good comparison with similar parameters on different SWL machines is lacking. Similar to other reported series, the relatively short followup of this study, although probably adequate for detecting scar formation and assessing GFR, might not allow for detection of subtle microvascular injury. Potential small or cumulative insults could contribute to pathological changes later in life. Despite these shortcomings, this information is important in deciding on a treatment plan, considering the recent advent of endoscopic devices that increase the success and safety of the retrograde approach to treating renal calculi in children.

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Despite the widespread acceptance of SWL for stone treatment in children, the potential long-term deleterious effects on the renal parenchyma remain incompletely defined. To address this issue, the authors present a well designed prospective study of 100 children who underwent treatment of renal stones with a modern lithotriptor. The importance of their investigation is amplified by animal studies revealing that the cavitation forces of SWL can cause direct tubular cell injury and microvascular damage, and possibly produce additional tissue injury by generation of free radicals.[1] Furthermore, earlier studies have demonstrated acute perfusion defects by DMSA scan following SWL.[2]

Based on the observed stability of preoperative and postoperative DTPA derived GFRs and the absence of acquired DMSA defects, the authors provide reassurance that SWL is a safe treatment modality in children. Clearly the reparative capacity of the pediatric kidney may erase transient changes as judged by these short-term studies. However, 2 important questions remain. Could there be significant post-SWL injury that exists below the resolution of the investigatory studies used in this report? Also, is there any potential for such an injury to evolve to clinical relevance, especially an increased risk of hypertension or proteinuria? Hopefully the authors will be able to follow this patient cohort into adulthood to provide answers to these questions.

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